



Physical and Mechanical Properties of Palm Oil Frond and Stem Bunch for Developing Pruner and Harvester Machinery Design

Yazid Ismi Intara¹⁾, H. Mayulu²⁾ and P.A.S. Radite³⁾

¹⁾Agro-technology Department of Agricultural Faculty, Mulawarman University

²⁾Animal Sciences Department of Agricultural Faculty, Mulawarman University

³⁾Mechanical and Biosystem Department of Agricultural Technology Faculty, Bogor Agricultural University.

¹Email: izmi_6@yahoo.com

Abstract - A development of oil palm pruner and harvester machinery design implemented in the field still faces a problem due to the lack of effective and efficient design which is need to be solved. It was noted that in order to develop the design, an early data and information of physical and mechanical properties of palm oil frond and stem fruits is critically important. The objective of the research was to obtain the physical and mechanical properties of palm oil frond and stem in order to develop the design of pruner and harvester machinery. The result showed that tool machinery was been advantageous by the physical properties of the plant i.e. the total weight of frond and leaf which enable to support the cutting process. The average of total weight of frond and leaf was 16.8 kg. The diagonal cutting trajectory was been more advantageous because of total weight and frond shape toward to the different of the plant tissue area. The measurement result shows that cutting curve follows the time required for cutting. The comparison among cutting curve shows differences in cutting thickness or length. In this case, the thickness is linear with cutting time. Besides, those curves show differences at the height which determine the maximum value of tested material cutting resistance. Alternative solution for machinery development design is pruner-harvester for height plant below 6 m and among 6 to 12 m. For below 6 m, pruner-harvester was designed by incorporating motor as power source and cutter-disc as the knife cutter. That condition was relied on that estate which was maintenance intensively commonly used cutter-disc. Pruner-harvester above 6 m and up to 12 m was improved based on manual egrek-designed by adding fresh fruit bunch alley supply glide in order to keep the fruits still in intact form. The consideration was based on affectivity and efficiency. It also considers homogenous ecological of palm oil plant which should be maintained to reduce global warming effect. Information obtained in this research could become positive consideration and alternative solution to provide problem solving at early development design of palm oil pruner and harvester machinery.

Keywords — physical-mechanical properties, palm oil frond, stem bunch, design, pruner, palm oil harvester

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I. INTRODUCTION

A harvesting process of palm oil is a cutting mechanism of the frond and stem bunch (Delmastro and Francesco, 1998). A research in cutting mechanism of palm oil harvesting is very important to be conducted in order to develop more effective, efficient and ergonomic to anticipate future global competition (Ahmad *et al.*, 2000). An engineering approach based on cutting mechanism of the frond and stem fruits analysis could be one of the answers. This analysis could provide basic parameter of the blade which enable to cut the frond and stem bunch efficiently (Yazid *et al.*, 2005^a). At this present, the basic research of pruner and harvester palm oil frond and stem

has not yet focused to the whole factors of physical, mechanical and structural properties of the plant material toward the cutting mechanism.

Perrson (1987) stated that knowledge of plant structure is very important to generate the reaction of plant material toward the cutting force and deformation. Thus could also provide the easiness to gain logical solution in order to develop cutting tool design. An understanding of the force occurred on a tool should be gained based on the material characteristic. The developed interaction can be not used if there are a different on size and structure between laboratory and real at the field (Holman and Gajda, 1989).

The plant tissue which will be used as the tested sample has specific mechanical properties. Deflection property is a displacement event of particular elements at the surface fiber in a layer thickness due to the bending which occurs up to underside of pressing area. The bending degree is influenced by the position of fiber in a particular layer and the thickness of the layer. A mathematical modeling of cutting force is highly influenced by the mechanical properties condition of the sample and force vector analysis employed in cutting process. This force will correlate toward the deformation properties of cut material (Yazid, 2005^b).

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During cutting process, the blade penetrates into the material, passing material strength which leads to material become split. In this process, material deformation is different which depends on the blade shape and cutting mechanical process (Sitkei, 1986).

Based on above consideration, the research was conducted to obtain field data and laboratory measurement upon the mechanical properties of palm oil frond and stem. The research was objected to obtain physical and mechanical properties of palm oil frond and stem to develop pruner and harvester machinery design of palm oil bunch.

II. MATERIAL AND METHOD

The research was conducted from June – September 2009 in:

1. Laboratory of Plantation Product Technology, Poltanesa Samarinda.
 2. Laboratory of Materials Strength, Department of Forest Product Technology, Faculty of Forestry, Mulawarman University, Samarinda.
 3. Palm Oil Plantation of Rea Kaltim Co., Tenggarong, Kutai Kartanegara.
- Materials and tools used were:

1. Universal Testing Machine (UTM) AMSLER (Type 10 Tuzes, Machine Nr 1999)
2. Deflecto meter (Mitutoyo Japan, 0.01 – 10 mms, No. 2046-08, Shock Proof)
3. Ruler, Protractor (CCKL Creator, Pat. 4.7666.675)
4. Weighing-meter, Knife Cutter, Dagger.

Figure 1 shows the technique to obtain the research material sample. The parameters which are observed and measured in frond and stem analysis were: a) stem bunch; b) fresh fruit bunch; c) leaf frond. The measurement consisted of: 1) weight and length of a) fresh fruit bunch and b) leaf frond; 2) angle and clearance between: a) stem and trunk; b) leaf frond and trunk; c) frond and frond, d) bunch and frond.

Measurement method to measure mechanical properties is shown in Fig. 2 which conducted to obtain these several parameters:

1. Elasticity Modulus (E)
2. Poisson ratio (ν)
3. Yield strength (s)
4. Strain (e)

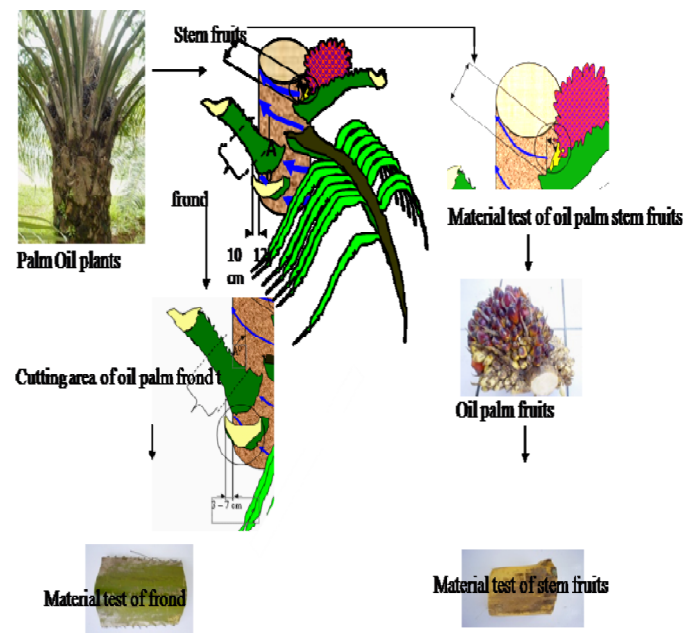


Fig 1. Technique to obtain frond and bunch fruit as material sample which is used in cutting test

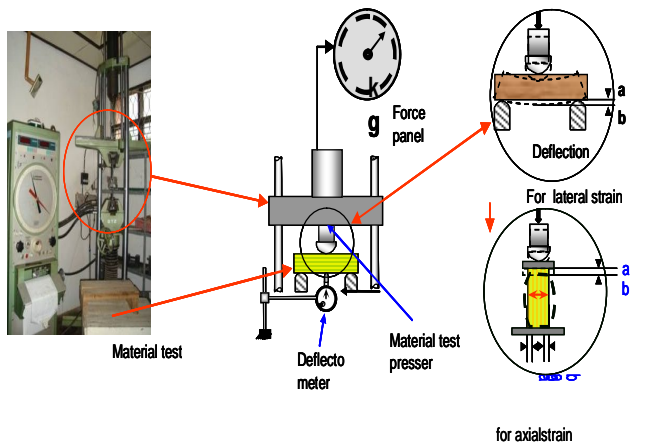


Fig. 2. Method to measure mechanical properties of palm oil frond and bunch

Universal Testing Machine which was used in the Laboratory of Materials Strength, Department of Forest Product Technology, Faculty of Forestry of Mulawarman University is shown in Figure 3.

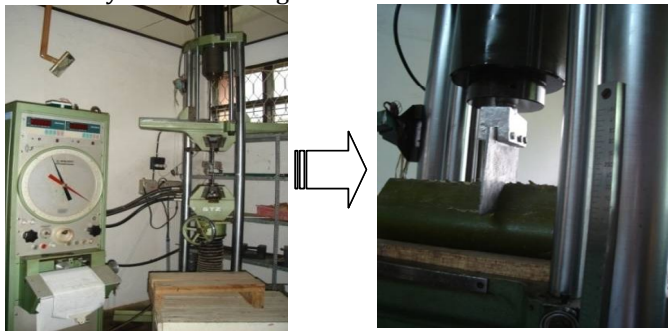


Fig. 3. Apparatus and method to measure cutting force palm oil frond and bunch

III. RESULT AND DISCUSSION

An observation of anatomy parts of palm oil frond and bunch is shown in Figure 4 consists of tissues which compose the plant structure. Frond part was composed of hard bark which consists of epidermis, collenchyma and sclerenchyma tissue. The soften part at the middle is parenchyma tissue which is used as material test. The determination of material test was carried out as an earlier research to obtain research of cutting intact frond. Besides, that part was considered as easier to be employed in laboratory test before developing prototype implemented in the field. Thus was supported by Perrson (1987) who stated that knowledge of plant structure is required to understand the reaction of material upon cutting force and deformation. It also eases to find logical solution to develop cutting tool design. Sometimes, some differences between tool which was used in laboratory scale and will be developed to be implemented in the field were occurred.

A characteristic measurement of palm oil bunch and frond was conducted in order to obtain physical

properties. The result of physical properties obtained in field measurement is shown in Table 1.

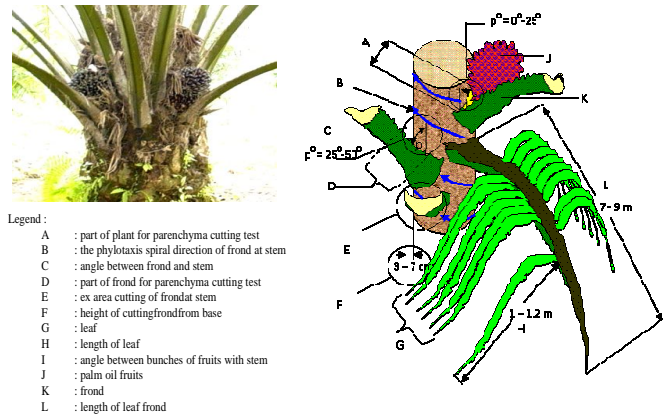


Fig. 5. Parenkhima frond and bunch as tested material at the field

The design of tool machinery was been advantageous by the physical properties of the plant, i.e. 1) the total weight of frond and leaf enabled to support the cutting process. The total weight of frond and leaf was 16.8 kg with frond surface area located at 12 cm from the stem was 96.8 cm². 2) The diagonal cutting trajectory was been more advantageous because of total weight and frond shape toward to the different of the plant tissue area. The plant tissue which was used as the sample had specific mechanical properties (Hanim and Siti-Norsafurah, 2012).

The cutting specific force analysis was greatly influenced by the mechanical properties of tested agricultural product. The bending degree was influenced by the position of fiber laid on a particular layer and the thickness of the layer. The point which lay on a particular thickness layer experienced bending movement up to the underside of the blade. The mathematic model development of cutting force would be influenced by the mechanical properties of the tested sample. Vector force analysis which occurred at cutting process would associate with deformation characteristic of the tested sample. The mechanical properties data of a material which was employed in cutting the palm oil parenchyma is showed in Table 2. Material deflection data was gained from stress and strain measurement which was then used to determine modulus elasticity (E), strength (σ), strain (ϵ), and poisson ratio (ν).

The result of cutting force could be simulated which shows graph in Fig. 6. In the cutting mechanism of palm oil frond using knife cutter, the length of cutting is the function between time (s) and force (daN/cm). The measurement of palm oil cutting was conducted at laboratory using flat knife cutter with sharpness angle at 10° applied in UTM. The frond as tested material was in intact form which was cut at different area i.e. 25%, 50% and 75%.

Table 1. Physical properties of palm oil plant

Num	Part of plant material	Parameter	Size
1	Frond	1. angelbetweenfrond and stem	25 ⁰ – 50 ⁰
		2. weight of leaf sandfrond	5.7 - 8.3 kg
		3. width of frondat area cutting	15 – 20 cm
		4. area of cutting frond section	41.25 – 62 cm ²
		5. clearance of cutting frond from base	
		6. length of frondfrom base till leaf end	3 – 7 cm
		7. amount of leaves	7 – 9 m
		8. length of per leaf	200 – 320 leaf
		9. shape of frond sectionis triangle shape	1 – 1.2 m
2	Stem bunch	1. angel between bunch and stem in cutting area	0 ⁰ – 35 ⁰
		2. weight of palm oil fresh bunch	8 – 21 kg
		3. diameter of fruit bunch	5 -7 cm
		4. cutting area of bunch at stem and frond	6 - 9.5 cm
		5. shape of stem of fruits iselips – circle	0 ⁰ – 15 ⁰
3	Longitudinal section of frond	1. Epidermis (outer bark which consists of wax layer andchlorophyl fiber tissue)	0.05 - 0.1cm
		2. Sclerenchymaand colenchyma (the hardest layer)	0.3 - 0.7 cm
		3. Parenchyma (soft tissueconsist of fiber)	5 - 8 cm
4	Longitudinal section of bunch stem	1. Epidermis (outer bark which consists wax layer and chlorophyl fiber tissue)	0.05 - 0.1cm
		2. Sclerenchyma and colenchyma (the hardest layer)	0.2 - 0.4 cm
		3. Parenchyma (soft tissue consists of fiber and pith)	4 – 5 cm

Palm oil plantation of Rea Kaltim Co. Ltd,Tenggarong,East Kalimantan.

Table 2. The mechanical properties of tested material (frond and palm oil bunch)

Material sample test	weight	length	deflection	inertia	axial max		MOE	
	p	L		I			E	
Intact frond	158	0.3	0.0112	0.0074	195.66	1070.17	psi	104.87 daN/cm ²
Stem bunch	14	0.1	0.0021	0.00026	41.66	509.66	psi	49.94 daN/cm ²
frond 25%	100	0.3	0.0227	0.0074		333.74	psi	32.70 daN/cm ²
frond 50%	100	0.3	0.0202	0.0074		374.97	psi	36.74 daN/cm ²
frond 75%	100	0.3	0.0132	0.0074		572.92	psi	56.14 daN/cm ²
Material sample test	strain (e)	yield strength		poisson ratio	Friction coef.	Blade thickness	Height of material	wide
	e	s =e * E		n	m	d	H	
Frond intact	0.0373	3.91	daN/cm ²	0.807	0.39	0.00015	56 mm	152 mm
Stem of fruits	0.0214	1.07	daN/cm ²	0.336	0.34	0.00015	42 mm	40 mm

The measurement result shows that cutting curve follows the time required for cutting. The comparison among cutting curve shows differences in cutting thickness or length. In this case, the thickness is linear with cutting time. Besides, those curves show differences at the height which determine the maximum value of tested material cutting resistance. The technical problems occurred during palm oil cutting and harvesting applied in the field is shown in Table 3.

Table 3 shows the importance of developing pruner and harvester design to replace the manual tool in order to provide more effective and efficient palm oil maintenance and harvester process. Further solution is to design pruner-harvester for height below 6 m and among 6 to 12 m. For below 6 m, pruner-harvester was designed by

incorporating motor as power source and cutter-disc as the knife cutter. That condition was relied on that estate which was maintenance intensively commonly used cutter-disc. Pruner-harvester above 6 m which could reach 12 m was improved based on manual *egrek*-designed by adding fresh fruit bunch alley supply glide in order to keep the fruits still in intact form. The consideration was based on affectivity and efficiency. It also considers homogenous ecological of palm oil plant which should be maintained to reduce global warming effect (to lessen plant rejuvenation and replanting)

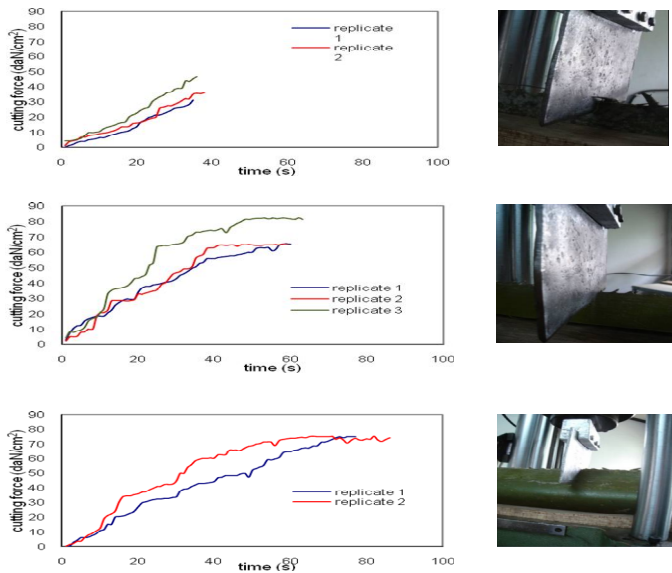


Fig. 6. The measurement result uses flat knife at sharpness 10°(crosscut angle = 0)

IV. CONCLUSION

1. The cutting frond part was composed of hard bark which consists of epidermis, collenchyma and sclerenchyma tissue. The soften part at the middle is parenchyma tissue which can improve cutting process.

2. The design of tool machinery was been advantageous by the physical properties of the plant, i.e. 1) the total weight of frond and leaf enabled to support the cutting process. The total weight of frond and leaf was 16.8 kg with frond surface area located at 12 cm from the stem was 96.8 cm². The diagonal cutting trajectory was been more advantageous because of total weight and frond shape toward to the different of the plant tissue area.
3. The plant tissue which was used as the sample had specific mechanical properties. The mathematic model development of cutting force would be influenced by the mechanical properties and force vector which associate with deformation characteristic of the tested sample. Material deflection data was gained from stress and strain measurement which was then used for determining modulus elasticity (E), strength (σ), strain (ϵ), and poisson ratio (ν).
4. The measurement result shows that cutting curve follows the time required for cutting. The comparison among cutting curve shows differences in cutting thickness or length. In this case, the thickness is linear with cutting time. Besides, those curves show differences at the height which determine the maximum value of tested material cutting resistance.
5. Further development is to design pruner-harvester for plant height below 6 m and among 6 to 12 m.

Table 3. Technical problems occurred in palm oil cutting and harvesting in the field

Num	Problem	Consideration matter
1	Palm oil harvesting is an activity to pick the product from the plant.	<ol style="list-style-type: none"> a. cutting of mature bunch stem b. picking the harvest yield c. transport the harvested product to the mill
2	Palm oil harvesting tools are still traditional which is operated manually, it is called <i>dodos</i> and <i>egrek</i>	<ol style="list-style-type: none"> a. It is still considered as efficient for big mill b. Laborer is still quite cheap, especially in Asia c. Price is affordable and easily to be produced
3	Harvesting process should consider former frond cutting	<ol style="list-style-type: none"> a. Maintenance activity of cutting frond before harvesting is very important, because it eases the using of harvesting tool b. Frond cutting should be conducted prior harvesting the bunch c. The direction of cutting (<i>dodos</i>) is performed beside the frond d. <i>Dodos</i> is manually push mechanism harvesting tool e. <i>Egrek</i> is manually pull mechanism harvesting tool.
4	Dropped palm oil fruits should be picked and then collected on a container	<ol style="list-style-type: none"> a. Picking dropped fruits is wasting time and lowering the efficiency process b. In a slop topography area, picking is more wasting time. Sack can be an alternative.
5	Operator complaint	<ol style="list-style-type: none"> a. Traditional tools required high energy for carrying out maintenance and harvest b. Picking dropped fruits is wasting time c. Operator needs one wheel container for assisting the harvesting activity

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